# Nye 179 Poly-α-Olefin Estimated Vapor Pressure as a Function of Oil Loss at 40°C

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The vapor pressure as a function of oil loss at 40°C for Nye 179 poly-α-olefin (PAO) oil has been modeled using our in-house vapor pressure computer model.

**15. SUBJECT TERMS**

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# 1. Introduction

Spacecraft mechanisms use lubricants that must withstand the rigors of the orbital environment. The loss of lubricant via evaporation from the mechanism under low external pressure conditions can limit mechanism life. In order to be able to estimate the lubricant loss rate, it is necessary to know the vapor pressure of the lubricant at the temperature of the application, as well as the design of the mechanism. Historically, vapor pressures have been estimated using several oil vapor pressures measured at high temperatures that were extrapolated to lower temperatures under the assumption that the Clausius-Clapeyron relationship (log vapor pressure is linear with reciprocal absolute temperature) is linear over the temperature range of the application. This approach has two difficulties: The vapor pressure is usually representative of the light ends of the oil, and the linearity of the Clausius-Clapeyron relationship is an approximation for small temperature ranges; i.e., it is actually expected to be curved over large temperature ranges.

A spacecraft program used consultants to provide an estimate for the oil loss rate for a mechanism. The vapor pressure of the oil involved, Nye 179 poly-$\alpha$-olefin (PAO), was estimated from loss rate measurements. The loss rate led to a vapor pressure of $5 \times 10^{-9}$ torr at 40°C. However, the consultants used a value of $5 \times 10^{-11}$ torr in their mechanism loss rate calculations. This value is too low and would result in a projected mechanism life that was not conservative. The program office asked us to evaluate the vapor pressure of the PAO.

We have developed a computer model that can be used to estimate the vapor pressure of the oil as a function of oil loss.[*] The model uses supercritical fluid chromatography data to represent the molecular weight distribution of the oil components and linear hydrocarbon vapor pressure data corrected for curvature in the log vapor pressure vs 1/T relationship. This approach has been used to model the loss of several lubricants and exhibited excellent correlation with actual measured loss from mechanisms.[*] Our vapor pressure model was used to model the vapor pressure vs oil loss behavior of Nye 179 poly-$\alpha$-olefin (PAO) oil at 40°C.

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[*] D. J. Carré and P. A. Bertrand, "A Model to Calculate Evaporative Oil Loss in Spacecraft Mechanisms," *Tribology Trans.*, 42(2), 282 (1999).

## 2. Discussion

The starting point was the supercritical fluid (SFC) chromatogram of the oil. This is shown in Figure 1. Using hydrocarbon calibration data, the retention times were associated with carbon numbers (proportional to molecular weight) for modeling purposes. The SFC data were converted to Detector Response vs Carbon Number. This is shown in Figure 2. Although this PAO is expected to have molecular weights associated with multiples of 10 carbon atoms, the SFC data relates the pseudo boiling point (solubility in supercritical carbon dioxide) of linear hydrocarbons to the boiling points of the components in the oil. Linear hydrocarbons have higher boiling points than branched isomers, like PAOs. As a result, the PAO components are represented by model components with lower carbon numbers. Since the square root of the molecular weight appears in the loss and vapor pressure modeling, the errors introduced by the molecular weight differences between the model components and the actual components in the oil are very small.

The components of the oil consist of four groups, with the group at carbon number ~20 contributing ~3% of the components. This 4-modal distribution will give rise to a log vapor pressure vs percent
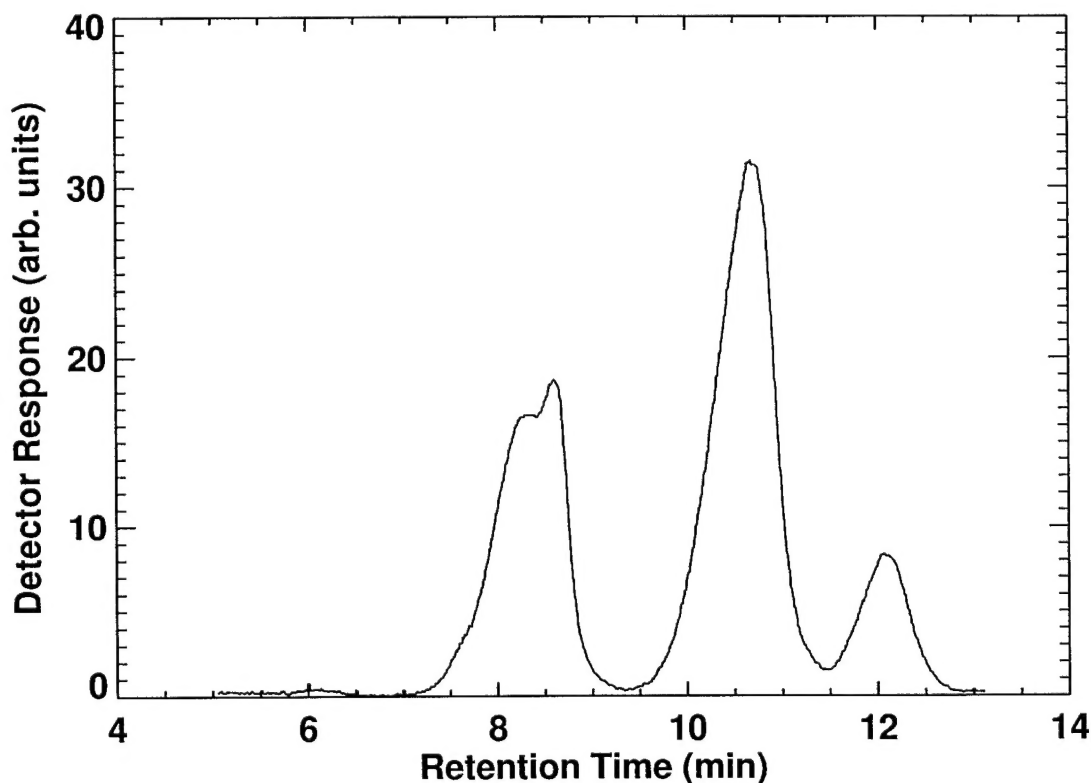
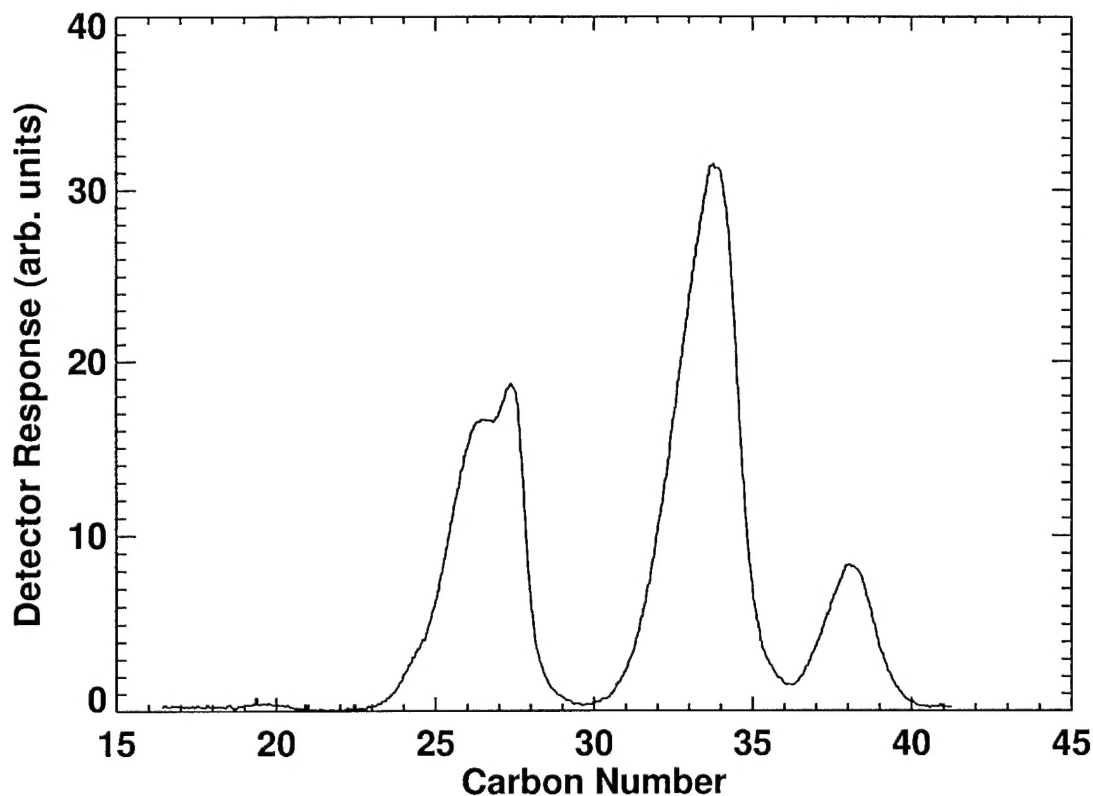Figure 1. SFC chromatogram of Nye 179 oil.

Figure 2.  SFC of Nyc 179 converted to carbon number.

oil loss curve that is not a smooth line, but would reflect the loss of each of the "peaks" in the distribution.  This is shown in Figure 3.  The initial vapor pressure of the unused oil from the model at 0% oil loss is ~7 x $10^{-7}$ torr at 40°C.  Our model predicts that 30% of the oil has a higher vapor pressure than the 5 x $10^{-9}$ torr derived from the consultants' loss rate data.  In addition, our model predicts that ~85% of the oil components have vapor pressures higher than the 5 x $10^{-11}$ torr used in the mechanism loss rate and life calculations.  Thus, the model suggests that the consultants under-predict the oil loss.

The change in the component distribution predicted by our computer model is illustrated in Figure 4, in which ~42% of the oil has been lost.  At this point, the two more volatile component groups have been lost.  This is consistent with Figure 3 in which the vapor pressure exhibits a large decrease at ~40% loss, indicating that the next less volatile group of components, centered about carbon number 34, have much lower vapor pressures than the components that have already been lost.

To convert the vapor pressures to lower or higher temperatures in this temperature range, a factor of 3 change for each 10°C change in temperature is a good approximation.

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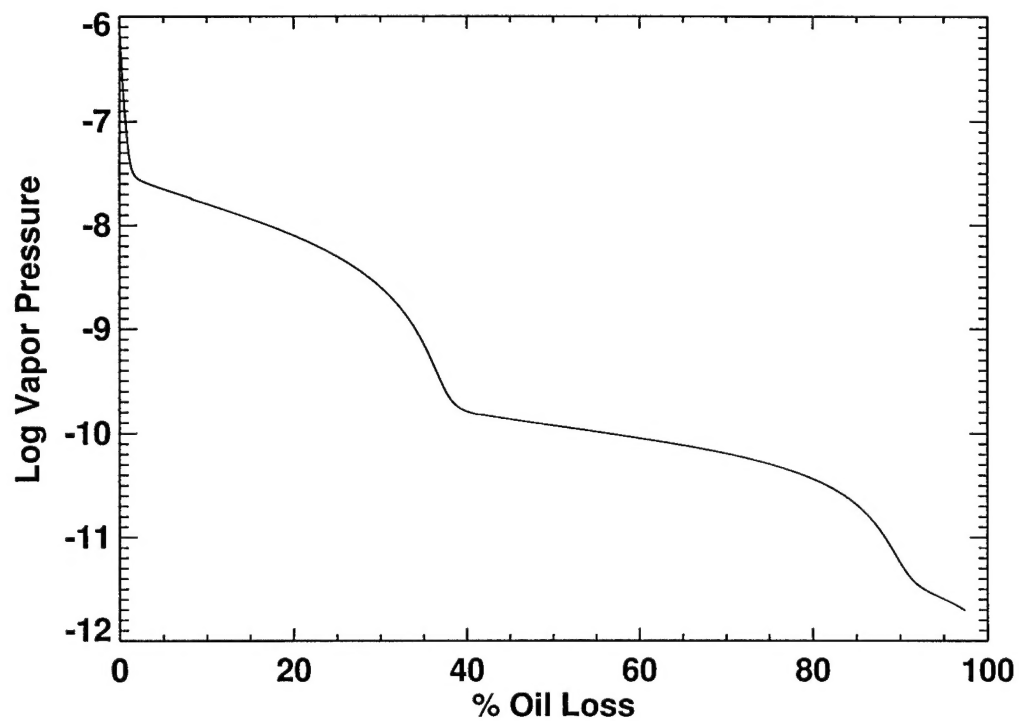
Figure 3. Log vapor pressure vs % oil loss for Nye 179 oil at 40°C.
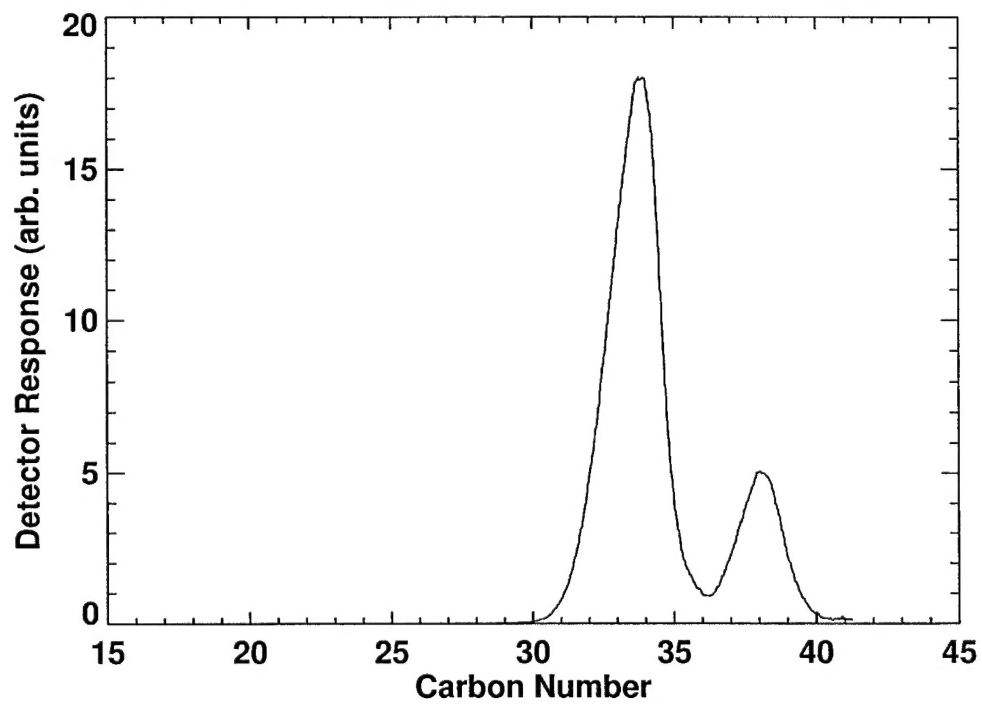


Figure 4. Nye 179 oil distribution at ~42% oil loss.

# 3. Summary

Our modeling suggest that the consultants used a value for the vapor pressure of the PAO oil that led to an under-prediction of the mechanism oil loss. The value of $5 \times 10^{-9}$ torr derived from the loss rate data is lower than the vapor pressures of 30% of the oil components, and the $5 \times 10^{-11}$ torr value used in the calculations of mechanism loss is lower than the values of ~85% of the components.

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